Optimized In-vivo High-Resolution Monkey DTI in Practice

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Introduction: DTI coupled with fiber tracking algorithm provides a unique tool for studying the brain structure and function non-invasively. The DTI applications range from brain development, functional study, brain tumors and white matter abnormalities such as Alzheimer's disease, HIV and multiple sclerosis [1]. Non-human primate brain has been widely used in related studies because it has similar structure and function with human brain. Currently most of the macaque brain MR studies are under ex-vivo fixed condition. However, the fixing procedure and tissue decomposition can cause the bias of the diffusion properties [2]. The function related studies and longitudinal studies also demand the in-vivo scan. The complex anatomical structure of many small but important area need high-resolution image to delineate. Diffusion tensor metrics such as the fractional anisotropy (FA) and apparent diffusion coefficient (ADC) can be biased in low spatial resolution because the partial volume effect. In this study, an optimized in-vivo high-resolution monkey DTI scan procedure was proposed and the impact of scan resolution on fiber tracking was analyzed.

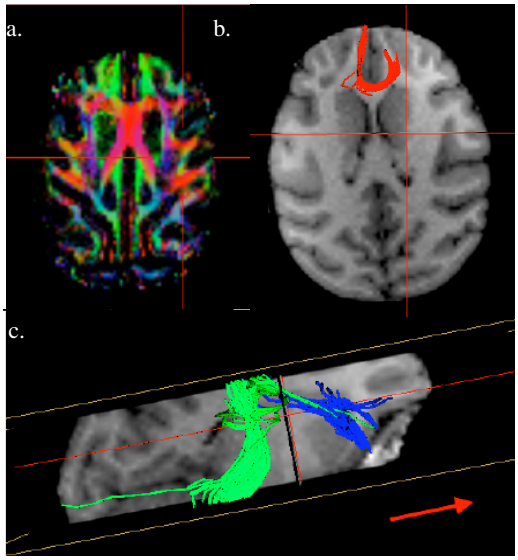

Fig.1. The color coded FA map (a). The fiber tracking result with the seed region manually placed on the forceps minor (b), and on the posterior internal capsule (green) and anterior internal capsule (blue) (c).

Materials and Method: The DTI data for monkeys were acquired on a 3T Siemens Trio MR scanner (Erlangen, Germany). The monkey was anaesthetized with sodium pentobarbitol, placed in a specially constructed MRI-compatible stereotaxic frame, intubated and continuously monitored by ECG. A homemade 3-channel phase array coil was used to increase the SNR and reduce susceptibility artifacts. TE/TR: 93ms/2900ms; Slice number: 20; slice thickness: 1mm; FOV: 96mm*96mm; Voxel size: 1mm*1mm*1mm; Diffusion direction: 24 (with 4 b0 images); b value: 700; Average:16; scan time is about 24 min. The short echo train used in this protocol can effectively reduce the susceptibility distortion. The ratio of number of DW images to non-DW images was 6:1 to reduce the bias of diffusion tensor calculation [3]. One set of T2W image and one set of phase map were acquired as well. Susceptibility and eddy current artifacts were corrected using the acquired field map and affine coregistration between non-DW image and DW images. To analyze the relationship between scan resolution and the fiber tracking result, the original high-resolution image data was resized to the desired resolution, then the data was interpolated back to 1mm cubic resolution for comparison. The diffusion tensor calculation and fiber tracking were performed using Volume one with dtv-II plugin. Identical seed regions were placed on the same position for data at each resolution level. Fiber tracking results were overlaid on the coregistered T2W structure image.

Result and Discussion: Using the proposed optimized in-vivo high-resolution monkey DTI protocol, we are able to derive the diffusion tensor and track the fiber with the DTI data acquired in an acceptable scan time. Fig 1a) shows the color FA map, with many details of the white fiber structure seen. Fig 1b) and 1c) shows the fiber tracking result with seed region in some main white matter structures. The result is comparable with results in the fixed brain scan in literature [2].

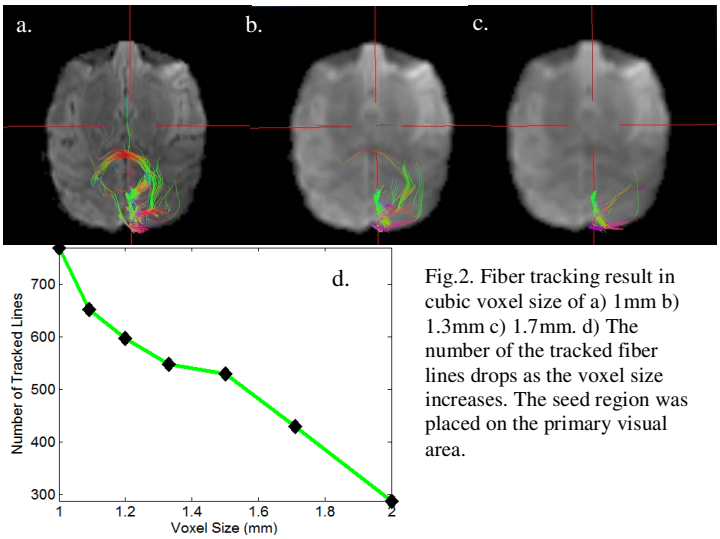

Fig.2. Fiber tracking result in cubic voxel size of a) 1mm b) 1.3mm c) 1.7mm. d) The number of the tracked fiber lines drops as the voxel size increases. The seed region was placed on the primary visual area.

Fig 2. shows the relationship between scan resolution and fiber tracking results. The seed region was placed within the primary visual area. With the original high-resolution data, the fiber was correctly tracked to delineate the actual structure. With the increase of the voxel size, the number of tracked fiber lines drops. When the resolution becomes too low, the fiber tracking failed. This trend is shown quantitatively in Fig 2d). Fiber tracking results with seed region on other positions show the same trend (figure not shown here). The result suggests that it is important to collect the real high-resolution data instead of interpolation for accurate diffusion tensor calculation and fiber tracking.

Reference

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